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Toronto Reservoir Greenwood and Woodson Counties, Kansas

National Eutrophication Survey, Corvallis, Oreg.

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT

ON

TORONTO RESERVOIR

GREENWOOD AND WOODSON COUNTIES

KANSAS

EPA REGION VII

WORKING PAPER No. 523

WITH THE COOPERATION OF THE

KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT

AND THE

KANSAS NATIONAL GUARD

APRIL, 1977

iv.

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Kansas State Department of Health and Environment for professional involvement, to the Kansas National Guard for conducting the tributary sampling phase of the Survey, and to those Kansas wastewater treatment plant operators who voluntarily provided effluent samples and flow data.

The staff of the Kansas Division of Environmental Health provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

Major General Edward R. Fry, the Adjutant General of Kansas, and Project Officer Colonel Albin L. Lundquist, who directed the volunteer efforts of the Kansas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY RESERVOIRS

STATE OF KANSAS

NAME	COUNTY
Cedar Bluff	Trego
Council Grove	Morris
Elk City	Montgomery
Fall River	Greenwood
John Redmond	Coffey, Lyon
Kanopolis	Ellsworth
Marion	Marion
Melvern	Osage
Milford	Clay, Geary
Norton	Norton
Perry	Jefferson
Pomona	Osage
Toronto	Greenwood, Woodson
Tuttle Creek	Marshall, Pottawatomie, Riley
Wilson	Russell

79°15'
79°00'
43°15'
43°00'
Bernard
Bronte
Madison
Creek
Creek
Creek
Creek
Creek
Creek
Creek
Creek
Creek
Creek
Creek
Creek
Creek
Creek
Creek
A2
C1
C2
D1
B1
B2
A1
Kan.
Map Location
TORONTO RESERVOIR
60 Tributary Sampling Site
Lake Sampling Site
Sewage Treatment Facility
Drainage Area Boundary
Land Subject to Inundation
0
30
60 Km.
0
5
10 Mi.
Scale
TORONTO RESERVOIR

TORONTO RESERVOIR
SICRET NO. 2013

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate Toronto Reservoir is potentially eutrophic. However, the reservoir becomes quite turbid during periods of runoff, and primary productivity is intermittently light-limited (Kring, 1977).

This water body ranked seventh in overall trophic quality when the 15 Kansas reservoirs sampled in 1974 were compared using a combination of six parameters*. Nine of the reservoirs had less median total phosphorus, five had less and one had the same median orthophosphorus, four had less median inorganic nitrogen, three had less mean chlorophyll a, and eleven had greater mean Secchi disc transparency.

B. Rate-Limiting Nutrient:

The algal assay results indicate the reservoir was phosphorus limited at the times the assay samples were taken (04/10/74 and 10/02/74).

The reservoir data also indicate phosphorus limitation at those times. However, the low Secchi disc transparencies and numbers of phytoplankton (page 7) indicate primary productivity is light-limited at times rather than nutrient-limited as noted above.

* See Appendix A.

C. Nutrient Controllability:

1. Point sources--Point sources contributed 9.0% of the total phosphorus load to Toronto Reservoir during the sampling year. The Hamilton, Madison, and Toronto wastewater treatment plants added 1.6%, 5.3%, and 2.0%, respectively. Septic tanks serving shoreline dwellings and recreational areas contributed an estimated 0.1% of the phosphorus load.

The present phosphorus loading of 2.26 $g/m^2/yr$ is nearly twice that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 14). However, the median hydraulic retention time of the reservoir is a short 22 days, and Vollenweider's model probably is not applicable.

Even complete removal of phosphorus at the point sources noted above would still leave a loading of 2.06 $g/m^2/yr$; and because primary productivity is light-limited part of the time, point-source phosphorus control would not be expected to result in a significant improvement in the trophic condition of Toronto Reservoir.

2. Non-point sources--The phosphorus contributions of non-point sources accounted for 91.0% of the total input to the reservoir during the sampling year. The Verdigris River contributed 31.1% of the total load; Walnut Creek, 17.5%; West Creek, 14.7%; and the ungaged minor tributaries and immediate drainage added an

estimated 26.9% of the total load.

The phosphorus export rates of the gaged tributaries were quite low (page 13) and are comparable to the rates of the two gaged tributaries of nearby Fall River Reservoir* (9 and 11 kg/km^2/yr).

* Working Paper No. 514.

II. RESERVOIR AND DRAINAGE BASIN CHARACTERISTICS[1]

A. Morphometry[11]:

1. Surface area: 11.13 kilometers^2.
2. Mean depth: 2.5 meters.
3. Maximum depth: 10.0 meters.
4. Volume: 28.73 x 10^6 m^3.
5. Fourteen-year median hydraulic retention time: 22 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Verdigris River	795.1	5.79
Walnut Creek	331.6	2.63
West Creek	306.6	2.42
Minor tributaries & immediate drainage -	491.2	3.88
Totals	1,923.4	14.72

2. Outlet -

Verdigris River	1,934.7**	14.42

C. Precipitation***:

1. Year of sampling: 114.5 centimeters.
2. Mean annual: 93.5 centimeters.

[1] Table of metric conversions--Appendix B.
[11] Kring, 1977.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of reservoir.
*** See Working Paper No. 175.

III. WATER QUALITY SUMMARY

Toronto Reservoir was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from two or more depths at two stations on the reservoir (see map, page v). During each visit, a single depth-integrated (4.6 m or near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 6.1 meters at station 1 and 4.6 meters at station 2.

The sampling results are presented in full in Appendix D and are summarized in the following table (the June nutrient samples were not properly preserved and were not analyzed).

[illegible] SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR TURKEY HOLLOW
STUDY CASE 2013

CHARACTER	1ST SAMPLING [illegible] 4/10/14				2ND SAMPLING [illegible] 5/15/14				3RD SAMPLING (DRY SEASON)			
	RANGE		MEAN	MEDIAN	RANGE		MEAN	MEDIAN	RANGE		MEAN	MEDIAN
TEMP (C)	11.1	- 11.9	11.4	11.4	24.1	- 26.2	25.0	24.9	26.5	- 26.7	26.6	26.5
[illegible] (MG/L)	9.4	- 9.4	9.4	9.4	2.8	- 9.6	6.2	9.4	7.8	- 8.2	8.0	8.0
[illegible]	378.	- 395.	382.	380.	321.	- 348.	334.	335.	253.	- 278.	265.	274.
PH (STAND UNITS)	8.2	- 8.2	8.2	8.2	7.8	- 8.6	7.9	7.8	7.6	- 7.9	7.8	7.8
TOT ALK (MG/L)	146.	- 156.	174.	156.	[illegible]				122.	- 125.	124.	124.
TOT P (MG/L)	0.266	- 0.287	0.274	0.274	[illegible]				0.253	- 0.286	0.266	0.266
DIS(ED) P (MG/L)	0.211	- 0.224	0.217	0.213	[illegible]				0.183	- 0.215	0.199	0.197
NO2+NO3 (MG/L)	0.428	- 0.523	0.486	0.478	[illegible]				0.251	- 0.345	0.304	0.305
AMMONIA (MG/L)	0.159	- 0.188	0.172	0.164	[illegible]				0.123	- 0.153	0.137	0.133
KJEL N (MG/L)	0.381	- 0.488	0.398	0.405	[illegible]				0.288	- 0.488	0.371	0.373
INORG N (MG/L)	0.478	- 0.618	0.534	0.538	[illegible]				0.278	- 0.438	0.384	0.405
TOTAL N (MG/L)	0.478	- 1.029	0.884	0.492	[illegible]				0.468	- 0.968	0.638	0.705
CHLOPHYL A (UG/L)	12.7	- 13.7	12.9	12.8	2.3	- 2.3	2.3	2.3	3.5	- 5.8	4.7	4.7
SECCHI (METERS)	8.3	- 8.3	8.3	8.3	8.3	- 8.3	8.3	8.3	8.3	- 8.3	8.3	8.3

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/10/74	1. Stephanodiscus sp.	2,365
	2. Cryptomonas sp.	449
	3. Chroomonas sp.	393
	4. Melosira sp.	336
	5. Ankistrodesmus sp.	160
	Total	3,701
06/24/74	1. Cryptomonas sp.	256
	2. Chroomonas sp.	206
	3. Melosira sp.	127
	4. Stephanodiscus sp.	42
	Total	679
10/02/74	1. Anabaena sp.	101
	2. Cryptomonas sp.	101
	3. Chroomonas sp.	69
	4. Melosira sp.	69
	5. Chlamydomonas sp.	34
	Other genera	139
	Total	517

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
04/10/74	1	12.0
	2	13.5
06/24/74	1	2.1
	2	2.3
10/03/74	1	5.5
	2	5.9

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. April sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.010	0.465	5.1
0.050 P	0.060	0.465	12.3
0.050 P + 1.0 N	0.060	1.465	26.3
1.0 N	0.010	1.465	3.6

b. October sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.025	0.415	3.6
0.050 P	0.075	0.415	8.5
0.050 P + 1.0 N	0.075	1.415	18.3
1.0 N	0.025	1.415	3.7

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of Toronto Reservoir was high at the times the samples were taken (04/10/74 and 10/02/74). The lack of growth response to the addition of only nitrogen and the significant increase in yield when phosphorus alone was added, indicate that phosphorus was limiting at those times.

The reservoir data also indicate phosphorus limitation. The mean inorganic nitrogen to orthophosphorus ratios were 41 to 1 in April and 48 to 1 in October and phosphorus limitation would be expected. However, primary productivity is light-limited rather than nutrient-limited part of the time (Kring, 1977).

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Kansas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of May, June, and July when two samples were collected. Sampling was begun in October, 1974, and was completed in September, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Kansas District Office of the U.S. Geological Survey for the tributary sites nearest the reservoir.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*. Nutrient loads shown are those measured minus point-source loads, if any.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in kg/km^2/year, at station B-1 and multiplying the means by the ZZ area in km^2.

The operators of the Hamilton, Madison, and Toronto wastewater treatment plants provided monthly effluent samples but could not provide corresponding flow data. Therefore, nutrient loads were

* See Working Paper No. 175.

stimated at 1.134 kg P and 3.401 kg N/capita/year, and flows were
timated at 0.3785 m^3/capita/day.

A. Waste Sources:

1. Known municipal* -

Name	Pop. Served	Treatment	Mean Flow (m^3/d)	Receiving Water
Hamilton	363	stab. pond	137.4	Willow Creek
Madison	1,200	tr. filter	454.2	Vermigris River
Toronto	458	tr. filter	173.4	Vermigris River arm of Reservoir

2. Known industrial - None

* Treatment plant questionnaires.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Verdigris River	7,975	31.1
Walnut Creek	4,490	17.5
West Creek	3,760	14.7
b. Minor tributaries & immediate drainage (non-point load) -	6,875	26.9
c. Known municipal STP's -		
Hamilton	410	1.6
Madison	1,360	5.3
Toronto	520	2.0
d. Septic tanks* -	15	0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	200	0.8
Total	25,605	100.0

2. Outputs -

Reservoir outlet - Verdigris River 35,940

3. Net annual P loss - 10,335 kg.

* Estimate based on 40 shoreline dwellings and two campgrounds; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Verdigris River	222,380	34.7
Walnut Creek	114,615	18.0
West Creek	110,145	17.3
b. Minor tributaries & immediate drainage (non-point load) -	169,955	26.7
c. Known municipal STP's -		
Hamilton	1,235	0.2
Madison	4,080	0.6
Toronto	1,960	0.3
d. Septic tanks* -	565	0.1
e. Known industrial - None	-	-
f. Direct precipitation** -	12,230	1.9
Total	636,765	100.0

2. Outputs -

Reservoir outlet - Verdigris River 661,285

3. Net annual N loss - 24,520 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Verdigris River	10	280
Walnut Creek	14	146
West Creek	12	360

* Estimate based on 40 shoreline dwellings and two campgrounds; see Working Paper No. 175.
** See Working Paper No. 175.

E. Mean Nutrient Concentrations in Ungaged Stream:

Tributary	Mean Total P Conc. (mg/l)	Mean Total N Conc. (mg/l)
Dry Creek	0.053	1.092

F. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m²/yr	2.26	loss*	56.2	loss*

Vollenweider phosphorus loadings
(g/m²/yr) based on mean depth and 14-year median
hydraulic retention time of Toronto Reservoir:

"Dangerous" (eutrophic loading)	1.22
"Permissible" (oligotrophic loading)	0.61

* There was an apparent loss of nutrients during the sampling year. This may have been due to unknown and unsampled point sources discharging directly to the reservoir but more likely was due to insufficient outlet sampling in relation to the short hydraulic retention time of the reservoir.

V. LITERATURE REVIEWED

Kring, D. Lynn, 1977. Personal communication (revised reservoir morphometry; primary productivity). KS Dept. of Health & Environment, Topeka.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	[illegible] TOTAL P	[illegible] INORG N	SUB- [illegible] SEC	[illegible] CHLOR A	IN- [illegible] IN	[illegible] SECCHI DEPTH P
2001	CEDAR BLUFF RESERVOIR	0.017	0.055	431.667	4.217	10.900	0.054
2002	COUNCIL GROVE	0.069	0.638	465.855	5.789	10.400	0.029
2003	EL* CITY	0.030	0.598	490.400	3.222	24.300	0.051
2004	FALL RIVER RESERVOIR	0.053	0.478	485.667	7.583	9.200	0.036
2005	JOHN REDMOND RESERVOIR	0.116	1.451	492.667	9.467	8.200	0.026
2006	KANOPOLIS RESERVOIR	0.056	0.644	467.455	14.633	10.286	0.031
2007	MARION RESERVOIR	0.052	0.438	483.667	12.400	9.300	0.033
2008	MELVERN RESERVOIR	0.033	0.265	458.111	10.400	24.400	0.057
2009	MILFORD RESERVOIR	0.076	0.738	466.333	19.683	12.600	0.035
2010	NORTON RESERVOIR	0.022	0.110	476.750	21.360	8.300	0.035
2011	PERRY RESERVOIR	0.055	0.478	478.571	5.654	13.400	0.037
2012	POMONA RESERVOIR	0.048	1.244	481.333	5.312	13.300	0.021
2013	TORONTO RESERVOIR	0.067	0.425	482.500	6.583	13.000	0.031
2014	TUTTLE CREEK RESERVOIR	0.192	0.970	478.667	11.278	13.400	0.067
2015	WILSON RESERVOIR	0.023	0.265	445.222	6.867	13.400	0.054

1	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]
10	[illegible]	[illegible]	[illegible]
11	[illegible]	[illegible]	[illegible]
12	[illegible]	[illegible]	[illegible]
13	[illegible]	[illegible]	[illegible]
14	[illegible]	[illegible]	[illegible]
15	[illegible]	[illegible]	[illegible]
16	[illegible]	[illegible]	[illegible]

[illegible]

APPENDIX B

CONVERSION FACTORS

| | | |

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX E

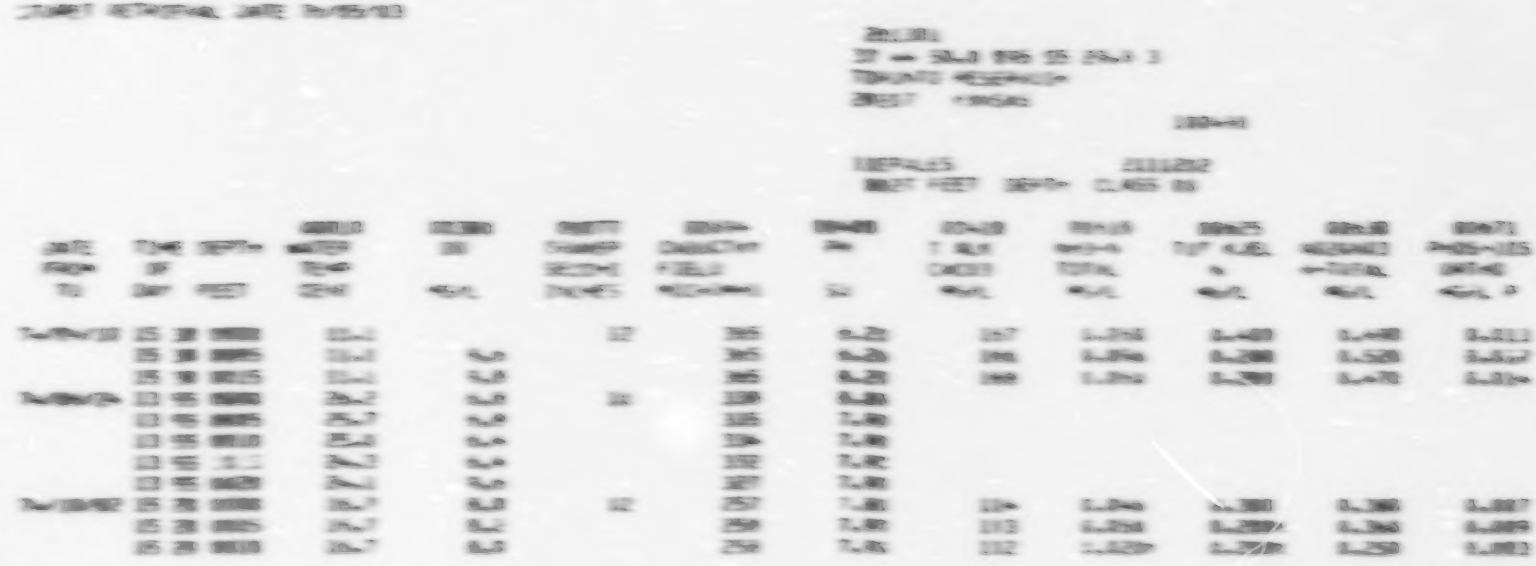
TRIBUTARY FLOW DATA

[illegible]

APPENDIX B

PHYSICAL and CHEMICAL DATA

[redacted]



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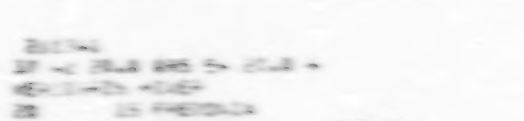
APPENDIX I

TRIBUTARY AND WASTEWATER TREATMENT PLANT DATA

[illegible]



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DATE	TIME	DEPT>	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FROM	OF		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	RATE	[illegible]
TO	DAY	FEET	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
75/07/11	11	00							
[illegible]			5,340	1,440	6,180	1,401	2,480		
75/07/11	16	00							
75/07/27	11	00							
[illegible]			5,210	3,980	6,360	5,460	1,380		
75/07/27	16	00							
75/04/30	11	00							
[illegible]			43,600	7,800	6,330	4,980	3,480		
75/04/30	16	00							
75/05/29	11	00							
[illegible]			18,500	1,400	6,240	7,480	2,480		
75/05/29	16	00							
75/06/25	11	00							
[illegible]			12,480	2,480	6,850	2,430	2,430		
75/06/25	16	00							
75/07/22	11	00							
[illegible]			22,500	5,380	6,850>	4,650	5,380		
75/07/22	16	00							
75/08/00	11	00							
[illegible]			24,800	6,480	6,270	4,850	6,380		
75/08/00	16	00							
75/09/25	11	00							
[illegible]			22,840	10,580	6,350	7,280	7,780		
75/09/25	16	00							
75/10/22	11	00							
[illegible]			6,880	27,880	5,880	4,380	4,380		
75/10/22	16	00							
75/11/21	11	00							
[illegible]			18,580	25,880	7,380	4,780	6,180		
75/11/21	16	00							
75/12/01	11	00							
[illegible]			4,980	15,480	4,780	6,880	7,480		
75/12/01	16	00							
75/12/22	11	00							
[illegible]			6,280	26,880	12,880	3,480	4,580		
75/12/22	16	00							

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340<

> VALUE FROM TO BE
> LESS THAN INDICATED

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			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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